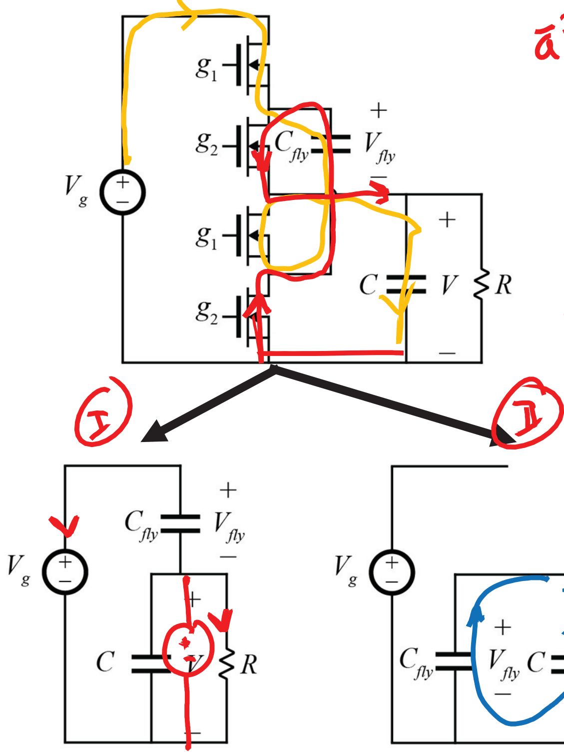
2:1 Converter Charge Vector Analysis



$$\vec{a}^{I} = [q_{in}^{I},\ q_{fly}^{I},\ q_{out}^{I}]/q_{out}$$

$$= [-1,\ 1,\ 1]/q_{out}$$

$$\vec{a}^{I} = [-1/2,\ 1/2,\ 1/2]$$

$$\vec{a}^{II} = [\emptyset,\ -1,\ +1]/q_{out}$$

$$\vec{a}^{II} = [0,\ -1/2,\ 1/2]$$

$$q_{out} = q_{out}^{I} + q_{out}^{II} = \underline{2}$$

$$\frac{q_{in}}{q_{out}} = \frac{q_{in}^{I} + q_{in}^{II}}{q_{out}} = -1/2$$

$\downarrow$

is a 2:1 converter

$$R_{o,SSL} = \sum_{caps} \frac{(a_{ci})^2}{C_i f_s} = \frac{1/4}{C_{fly} f_s} = \frac{1}{4 C_{fly} f_s} \quad \checkmark$$

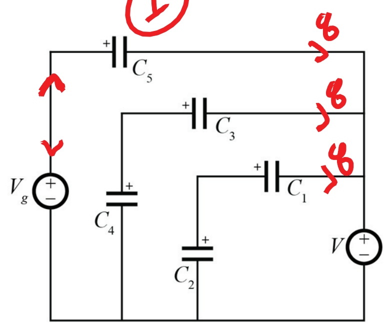
$$\bar{a}_r = [q_{r1},\ q_{r2},\ q_{r3},\ q_{r4}]/q_{out}$$

$$\bar{a}_r = [1/2,\ 1/2,\ -1/2,\ -1/2]$$

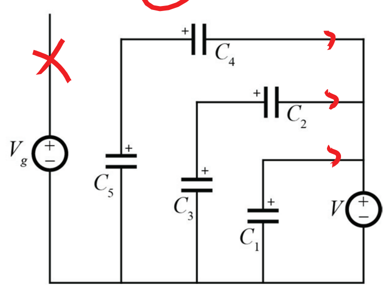
$$R_{o,FSL} = \sum_{i \in switches} 2R_{on,i}\,(a_{ri})^2 = \underline{2R_{on}} \quad \checkmark$$

Dickson Charge Vector Analysis

I



II



$$\bar{a}^{I} = [q_{in}^{I}, q_{c1}^{I}, q_{c2}^{I}, \dots, q_{c5}^{I}, q_{out}^{I}]/q_{out}$$

$$= [-1, 1, -1, 1, -1, 1, 3]/q_{out}$$

$$\bar{a}^{I} = [-1/6, 1/6, -1/6, 1/6, -1/6, 1/6, 1/2]$$

$$\bar{a}^{II} = [0, -1, 1, -1, 1, -1, 3]/q_{out}$$

$$\bar{a}^{II} = [0, -1/6, \dots, -1/6, 1/2]$$

$$\frac{q_{in}}{q_{out}} = \frac{1}{6} \Rightarrow 6:1 \text{ converter}$$

$$R_{o,SSL} = \sum_{i \in caps} \frac{(a_{c,i})^2}{C_i f_s} = \frac{5}{36} \frac{1}{C_{fly} f_s}$$

if $C_1 \cdots C_5 = C_{fly}$

Charge Vector Analysis in FSL

$$\bar{a}_r = \frac{\bar{q}_r}{q_{out}} \Rightarrow q_{r,i}$$ = charge that flows through switch i when it is conducting

↳ some linear combination of $\bar{a}^{I}$ & $\bar{a}^{II}$

in FSL, currents constant within I & II

i_{ri} = current in switch i when conducting

$$i_{ri} = q_{ri} \frac{2}{T_s}$$

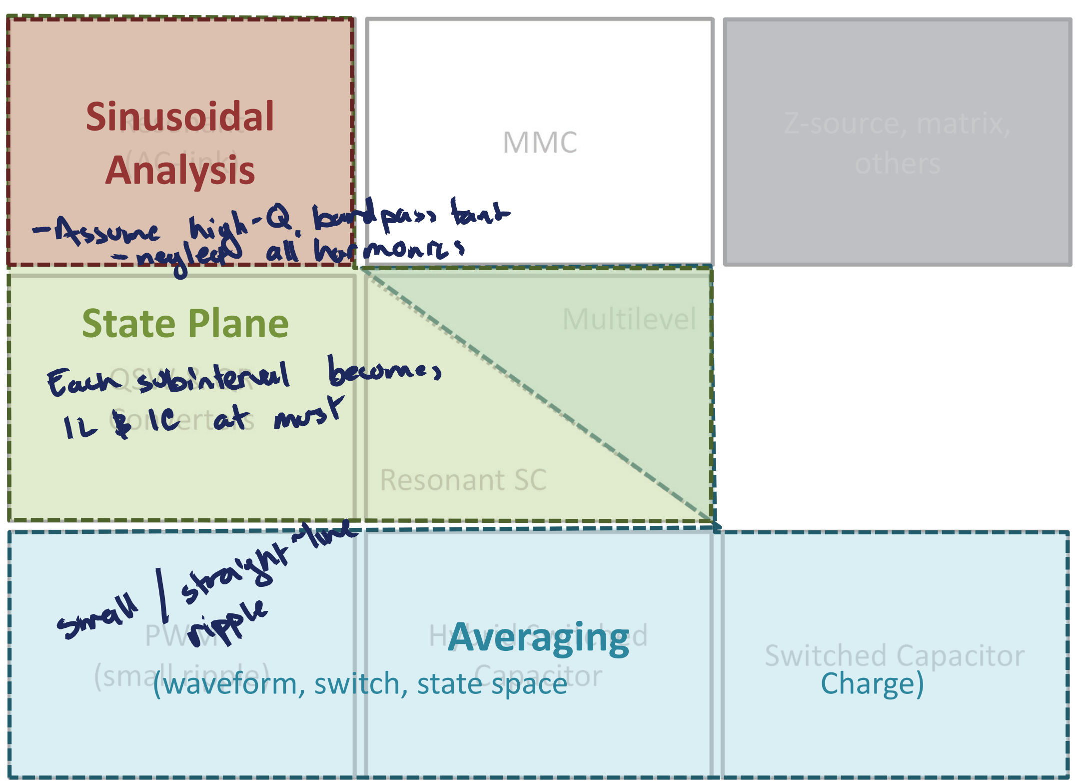
$$P_{ri} = (i_{ri})^2 R_{on,i} \cdot \overset{D}{\frac{1}{2}} = \left(q_{ri} \frac{2}{T_s}\right)^2 R_{on,i} \frac{1}{2} = q_{ri}^2 f_s^2 \cdot 2R_{on,i}$$

$$P_{ri} = a_{ri}^2 \underbrace{q_{out}^2 f_s^2}_{I_{out}^2} \cdot 2R_{on,i}$$

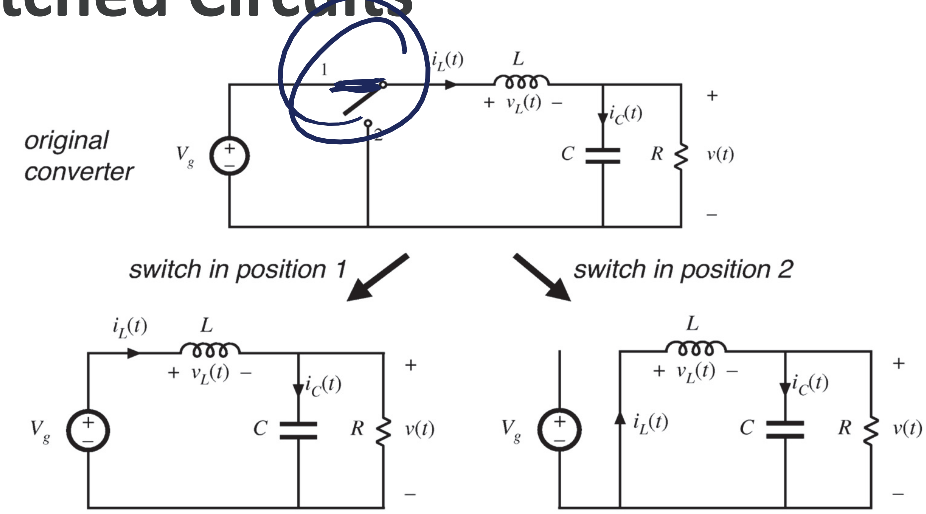
$$R_{o,FSL} = \sum_{i \in switches} 2R_{on,i} (a_{r,i})^2$$

DISCRETE TIME MODELING

Converter Analysis



Switched Circuits



Historical Perspective

Robert D Middlebrook
PhD, Standford, 1955
CalTech Professor, 1955-1998

Slobodan Cúk
PhD CalTech, 1976
CalTech Prof, 1977-1999

Modelling, analysis, and design of switching converters

Model a switched system as an averaged, time-invariant system with

$$\dot{\boldsymbol{x}}(t) = \boldsymbol{A}\boldsymbol{x}(t) + \boldsymbol{B}u(t)$$

where

$$\boldsymbol{A} = D\boldsymbol{A}_1 + D'\boldsymbol{A}_2$$
$$\boldsymbol{B} = D\boldsymbol{B}_1 + D'\boldsymbol{B}_2$$